



4004 SINGLE CHIP 4-BIT P-CHANNEL MICROPROCESSOR

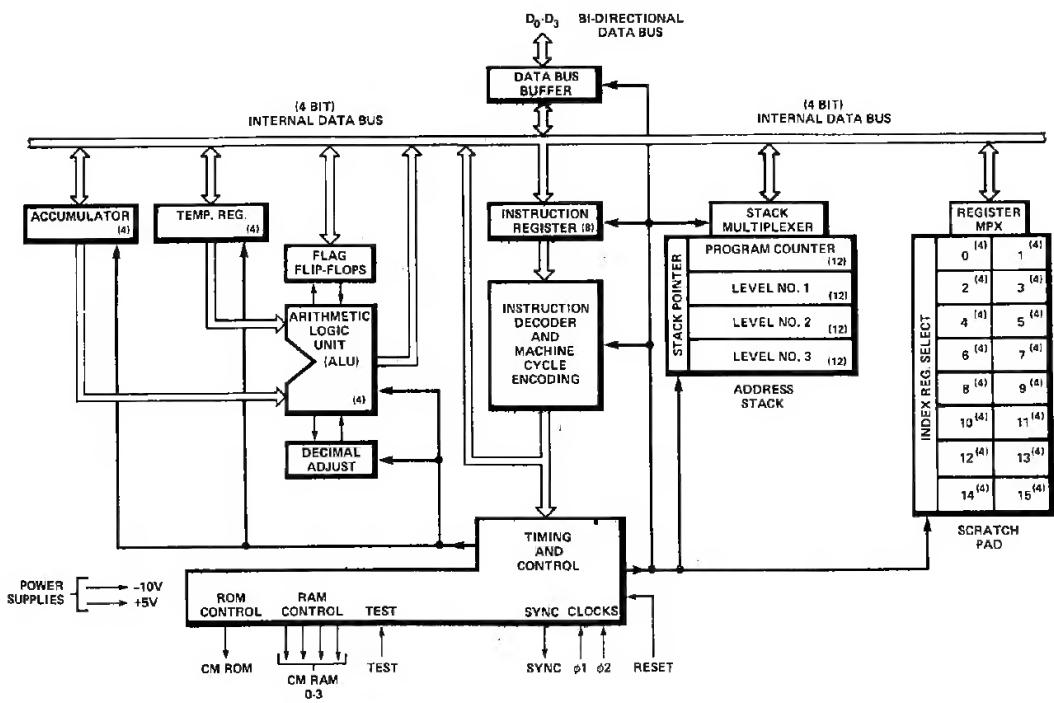
- 4-Bit Parallel CPU With 46 Instructions
- Instruction Set Includes Conditional Branching, Jump to Subroutine and Indirect Fetching
- Binary and Decimal Arithmetic Modes
- 10.8 Microsecond Instruction Cycle
- CPU Directly Compatible With MCS-40 ROMs and RAMs
- Easy Expansion – One CPU can Directly Drive up to 32,768 Bits of ROM and up to 5120 Bits of RAM
- Standard Operating Temperature Range of 0° to 70°C
- Also Available With -40° to +85°C Operating Range

The Intel® 4004 is a complete 4-bit parallel central processing unit (CPU). The 4004 easily interfaces with keyboards, switches, displays, A-D converters, printers and other peripheral equipment.

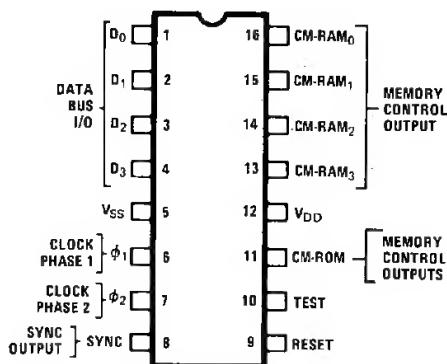
The CPU can directly address 4K 8-bit instruction words of program memory and 5120 bits of data storage RAM. Sixteen index registers are provided for temporary data storage. Up to 16 4-bit input ports and 16 4-bit output ports may also be directly addressed.

The 4004 is fabricated with P-channel silicon gate MOS technology.

MCS 4/40



Pin Description



D₀-D₃

BIDIRECTIONAL DATA BUS. All address and data communication between the processor and the RAM and ROM chips occurs on these 4 lines.

RESET

RESET input. A logic "1" level at this input clears all flags and status registers and forces the program counter to zero. To completely clear all address and index registers, RESET must be applied for 64 clock cycles (8 machine cycles).

TEST

TEST input. The logical state of this signal may be tested with the JCN instruction.

SYNC

SYNC output. Synchronization signal generated by the processor and set to the ROM and RAM chips. It indicates the beginning of an instruction cycle.

CM-ROM

CM-ROM output. This is the ROM selection signal sent out by the processor when data is required from program memory.

CM-RAM₀ – CM-RAM₃

CM-RAM outputs. These are the bank selection signals for the 4002 RAM chips in the system.

φ₁, φ₂

Two phase clock inputs.

V_{SS}

Most positive voltage.

V_{DD}

V_{SS} -15 ±5% main supply voltage.

Instruction Set Format

A. Machine Instructions

- 1 word instruction – 8-bits requiring 8 clock periods (instruction cycle).
- 2 word instruction – 16-bits requiring 16 clock periods (2 instruction cycles).

Each instruction is divided into two four-bit fields. The upper 4-bits is the OPR field containing the operation code. The lower 4-bits is the OPA field containing the modifier. For two word instructions, the second word contains address information or data.

The upper 4-bits (OPR) will always be fetched before the lower 4-bits (OPA) during M₁ and M₂ times respectively.

ONE WORD INSTRUCTIONS								TWO WORD INSTRUCTIONS															
D ₃ D ₂ D ₁ D ₀ D ₃ D ₂ D ₁ D ₀								1st INSTRUCTION CYCLE															
X X X X				X X X X				D ₃ D ₂ D ₁ D ₀				D ₃ D ₂ D ₁ D ₀											
OPR				OPA				OPR				OPA											
OP CODE MODIFIER								2nd INSTRUCTION CYCLE															
X X X X A ₃ A ₃ A ₃ A ₃								OP CODE MODIFIER															
INDEX REGISTER ADDRESS R R R R								MIDDLE ADDRESS LOWER ADDRESS															
OR								A ₂ A ₂ A ₂ A ₂ A ₁ A ₁ A ₁ A ₁															
X X X X C ₁ C ₂ C ₃ C ₄								MIDDLE ADDRESS LOWER ADDRESS															
INDEX REGISTER PAIR ADDRESS R R R X								A ₂ A ₂ A ₂ A ₂ A ₁ A ₁ A ₁ A ₁															
OR								INDEX REGISTER ADDRESS R R R R															
X X X X A ₂ A ₂ A ₂ A ₂ A ₁ A ₁ A ₁ A ₁								MIDDLE ADDRESS LOWER ADDRESS															
DATA D D D D								D ₂ D ₂ D ₂ D ₂ D ₁ D ₁ D ₁ D ₁															
INPUT/OUTPUT & RAM INSTRUCTIONS 1 1 1 0 X X X X								UPPER DATA LOWER DATA															
ACCUMULATOR GROUP INSTRUCTIONS 1 1 1 1 X X X X								D ₂ D ₂ D ₂ D ₂ D ₁ D ₁ D ₁ D ₁															

Table I. Machine Instruction Format

B. Input/Output and RAM Instructions and Accumulator Group Instructions

In these instructions (which are all single word) the OPR contains a 4-bit code which identifies either the I/O instruction or the accumulator group instruction and the OPA contains a 4-bit code which identifies the operation to be performed. Table II illustrates the contents of each 4-bit field.

D ₃ D ₂ D ₁ D ₀	X X X X	X X X X
OPR		OPA
INPUT/OUTPUT & RAM INSTRUCTIONS	1 1 1 0	X X X X
ACCUMULATOR GROUP INSTRUCTIONS	1 1 1 1	X X X X

WHERE X = EITHER A "0" OR A "1".

Table II. I/O and Accumulator Group Instruction Formats

4004 Instruction Set

BASIC INSTRUCTIONS (* = 2 Word Instructions)

Hex Code	MNEMONIC	OPR				OPA				DESCRIPTION OF OPERATION
		D ₃	D ₂	D ₁	D ₀	D ₃	D ₂	D ₁	D ₀	
00	NOP	0	0	0	0	0	0	0	0	No operation.
1 -	*JCN	0	0	0	1	C ₁	C ₂	C ₃	C ₄	Jump to ROM address A ₂ A ₂ A ₂ A ₂ , A ₁ A ₁ A ₁ A ₁ (within the same ROM that contains this JCN instruction) if condition C ₁ C ₂ C ₃ C ₄ is true, otherwise go to the next instruction in sequence.
--		A ₂	A ₂	A ₂	A ₂	A ₁	A ₁	A ₁	A ₁	
2 -	*FIM	0	0	1	0	R	R	R	0	Fetch immediate (direct) from ROM Data D ₂ D ₂ D ₂ D ₂ D ₁ D ₁ D ₁ to index register pair location RRR.
--		D ₂	D ₂	D ₂	D ₂	D ₁	D ₁	D ₁	D ₁	
3 -	FIN	0	0	1	1	R	R	R	0	Fetch indirect from ROM. Send contents of index register pair location 0 out as an address. Data fetched is placed into register pair location RRR.
3 -	JIN	0	0	1	1	R	R	R	1	Jump indirect. Send contents of register pair RRR out as an address at A ₁ and A ₂ time in the instruction cycle.
4 -	*JUN	0	1	0	0	A ₃	A ₃	A ₃	A ₃	Jump unconditional to ROM address A ₃ A ₃ A ₃ A ₃ A ₂ A ₂ A ₂ A ₂ A ₁ A ₁ A ₁ A ₁ .
--		A ₂	A ₂	A ₂	A ₂	A ₁	A ₁	A ₁	A ₁	
5 -	*JMS	0	1	0	1	A ₃	A ₃	A ₃	A ₃	Jump to subroutine ROM address A ₃ A ₃ A ₃ A ₃ A ₂ A ₂ A ₂ A ₂ A ₁ A ₁ A ₁ A ₁ , save old address (up 1 level in stack.)
--		A ₂	A ₂	A ₂	A ₂	A ₁	A ₁	A ₁	A ₁	
6 -	INC	0	1	1	0	R	R	R	R	Increment contents of register RRRR.
7 -	*ISZ	0	1	1	1	R	R	R	R	Increment contents of register RRRR. Go to ROM address A ₂ A ₂ A ₂ A ₂ A ₁ A ₁ A ₁ A ₁ (within the same ROM that contains this ISZ instruction) if result ≠ 0, otherwise go to the next instruction in sequence.
--		A ₂	A ₂	A ₂	A ₂	A ₁	A ₁	A ₁	A ₁	
8 -	ADD	1	0	0	0	R	R	R	R	Add contents of register RRRR to accumulator with carry.
9 -	SUB	1	0	0	1	R	R	R	R	Subtract contents of register RRRR to accumulator with borrow.
A -	LD	1	0	1	0	R	R	R	R	Load contents of register RRRR to accumulator.
B -	XCH	1	0	1	1	R	R	R	R	Exchange contents of index register RRRR and accumulator.
C -	BBL	1	1	0	0	D	D	D	D	Branch back (down 1 level in stack) and load data DDDD to accumulator.
D -	LDM	1	1	0	1	D	D	D	D	Load data DDDD to accumulator.
F0	CLB	1	1	1	1	0	0	0	0	Clear both. (Accumulator and carry)
F1	CLC	1	1	1	1	0	0	0	1	Clear carry.
F2	IAC	1	1	1	1	0	0	1	0	Increment accumulator.
F3	CMC	1	1	1	1	0	0	1	1	Complement carry.
F4	CMA	1	1	1	1	0	1	0	0	Complement accumulator.
F5	RAL	1	1	1	1	0	1	0	1	Rotate left. (Accumulator and carry)
F6	RAR	1	1	1	1	0	1	1	0	Rotate right. (Accumulator and carry)
F7	TCC	1	1	1	1	0	1	1	1	Transmit carry to accumulator and clear carry.
F8	DAC	1	1	1	1	1	0	0	0	Decrement accumulator.
F9	TCS	1	1	1	1	1	0	0	1	Transfer carry subtract and clear carry.
FA	STC	1	1	1	1	1	0	1	0	Set carry.
FB	DAA	1	1	1	1	1	0	1	1	Decimal adjust accumulator.
FC	KBP	1	1	1	1	1	1	0	0	Keyboard process. Converts the contents of the accumulator from a one out of four code to a binary code.
FD	DCL	1	1	1	1	1	1	0	1	Designate command line.

MOS
AS

4004

4001/4002/4008/4009/4289 INPUT/OUTPUT AND RAM INSTRUCTIONS

Hex Code	Mnemonic	OPR			OPA D ₃ D ₂ D ₁ D ₀	DESCRIPTION OF OPERATION	
		D ₃	D ₂	D ₁			
2 -	SRC	0	0	1	0	R R R 1	Send register control. Send the address (contents of index register pair RRR) to ROM and RAM at X ₂ and X ₃ time in the instruction cycle.
E0	WRM	1	1	1	0	0 0 0 0	Write the contents of the accumulator into the previously selected RAM main memory character.
E1	WMP	1	1	1	0	0 0 0 1	Write the contents of the accumulator into the previously selected RAM output port. (Output Lines)
E2	WRR	1	1	1	0	0 0 1 0	Write the contents of the accumulator into the previously selected ROM output port. (I/O Lines)
E3	WPM	1	1	1	0	0 0 1 1	Write the contents of the accumulator into the previously selected half byte of read/write program memory (used with 4008/4009 or 4289 only)
E4	WR0	1	1	1	0	0 1 0 0	Write the contents of the accumulator into the previously selected RAM status character 0.
E5	WR1	1	1	1	0	0 1 0 1	Write the contents of the accumulator into the previously selected RAM status character 1.
E6	WR2	1	1	1	0	0 1 1 0	Write the contents of the accumulator into the previously selected RAM status character 2.
E7	WR3	1	1	1	0	0 1 1 1	Write the contents of the accumulator into the previously selected RAM status character 3.
E8	SBM	1	1	1	0	1 0 0 0	Subtract the previously selected RAM main memory character from accumulator with borrow.
E9	RDM	1	1	1	0	1 0 0 1	Read the previously selected RAM main memory character into the accumulator.
EA	RDR	1	1	1	0	1 0 1 0	Read the contents of the previously selected ROM input port into the accumulator. (I/O Lines)
EB	ADM	1	1	1	0	1 0 1 1	Add the previously selected RAM main memory character to accumulator with carry.
EC	RD0	1	1	1	0	1 1 0 0	Read the previously selected RAM status character 0 into accumulator.
ED	RD1	1	1	1	0	1 1 0 1	Read the previously selected RAM status character 1 into accumulator.
EE	RD2	1	1	1	0	1 1 1 0	Read the previously selected RAM status character 2 into accumulator.
EF	RD3	1	1	1	0	1 1 1 1	Read the previously selected RAM status character 3 into accumulator.

MCS 440

4004 Instruction Codes

Hex	Mnemonic	Hex	Mnemonic	Hex	Mnemonic	Hex	Mnemonic	
00	-	40	JUN	80	ADD 0	C0	BBL 0	
01	-	41	JUN	81	ADD 1	C1	BBL 1	
02	-	42	JUN	82	ADD 2	C2	BBL 2	
03	-	43	JUN	83	ADD 3	C3	BBL 3	
04	-	44	JUN	84	ADD 4	C4	BBL 4	
05	-	45	JUN	85	ADD 5	C5	BBL 5	
06	-	46	JUN	86	ADD 6	C6	BBL 6	
07	-	47	JUN	87	ADD 7	C7	BBL 7	
08	-	48	JUN	88	ADD 8	C8	BBL 8	
09	-	49	JUN	89	ADD 9	C9	BBL 9	
0A	-	4A	JUN	8A	ADD 10	CA	BBL 10	
0B	-	4B	JUN	8B	ADD 11	CB	BBL 11	
0C	-	4C	JUN	8C	ADD 12	CC	BBL 12	
0D	-	4D	JUN	8D	ADD 13	CD	BBL 13	
0E	-	4E	JUN	8E	ADD 14	CE	BBL 14	
0F	-	4F	JUN	8F	ADD 15	CF	BBL 15	
10	JCN	CN=0	50	JMS	90	SUB 0	D0	LDM 0
11	JCN	CN=1 also JNT	51	JMS	91	SUB 1	D1	LDM 1
12	JCN	CN=2 also JC	52	JMS	92	SUB 2	D2	LDM 2
13	JCN	CN=3	53	JMS	93	SUB 3	D3	LDM 3
14	JCN	CN=4 also JZ	54	JMS	94	SUB 4	D4	LDM 4
15	JCN	CN=5	55	JMS	95	SUB 5	D5	LDM 5
16	JCN	CN=6	56	JMS	96	SUB 6	D6	LDM 6
17	JCN	CN=7	57	JMS	97	SUB 7	D7	LDM 7
18	JCN	CN=8	58	JMS	98	SUB 8	D8	LDM 8
19	JCN	CN=9 also JT	59	JMS	99	SUB 9	D9	LDM 9
1A	JCN	CN=10 also JNC	5A	JMS	9A	SUB 10	DA	LDM 10
1B	JCN	CN=11	5B	JMS	9B	SUB 11	DB	LDM 11
1C	JCN	CN=12 also JNZ	5C	JMS	9C	SUB 12	DC	LDM 12
1D	JCN	CN=13	5D	JMS	9D	SUB 13	DD	LDM 13
1E	JCN	CN=14	5E	JMS	9E	SUB 14	DE	LDM 14
1F	JCN	CN=15	5F	JMS	9F	SUB 15	DF	LDM 15
20	FIM	0	60	INC 0	A0	LD 0	E0	WRM
21	SRC	0	61	INC 1	A1	LD 1	E1	WMP
22	FIM	2	62	INC 2	A2	LD 2	E2	WRR
23	SRC	2	63	INC 3	A3	LD 3	E3	WPM
24	FIM	4	64	INC 4	A4	LD 4	E4	WRO
25	SRC	4	65	INC 5	A5	LD 5	E5	WR1
26	FIM	6	66	INC 6	A6	LD 6	E6	WR2
27	SRC	6	67	INC 7	A7	LD 7	E7	WR3
28	FIM	8	68	INC 8	A8	LD 8	E8	SBM
29	SRC	8	69	INC 9	A9	LD 9	E9	RDM
2A	FIM	10	6A	INC 10	AA	LD 10	EA	RDR
2B	SRC	10	6B	INC 11	AB	LD 11	EB	ADM
2C	FIM	12	6C	INC 12	AC	LD 12	EC	RDO
2D	SRC	12	6D	INC 13	AD	LD 13	ED	RD1
2E	FIM	14	6E	INC 14	AE	LD 14	EE	RD2
2F	SRC	14	6F	INC 15	AF	LD 15	EF	RD3
30	FIN	0	70	ISZ 0	B0	XCH 0	F0	CLB
31	JIN	0	71	ISZ 1	B1	XCH 1	F1	CLC
32	FIN	2	72	ISZ 2	B2	XCH 2	F2	IAC
33	JIN	2	73	ISZ 3	B3	XCH 3	F3	CMC
34	FIN	4	74	ISZ 4	B4	XCH 4	F4	CMA
35	JIN	4	75	ISZ 5	B5	XCH 5	F5	RAL
36	FIN	6	76	ISZ 6	B6	XCH 6	F6	RAR
37	JIN	6	77	ISZ 7	B7	XCH 7	F7	TCC
38	FIN	8	78	ISZ 8	B8	XCH 8	F8	DAC
39	JIN	8	79	ISZ 9	B9	XCH 9	F9	TCS
3A	FIN	10	7A	ISZ 10	BA	XCH 10	FA	STC
3B	JIN	10	7B	ISZ 11	BB	XCH 11	FB	DAA
3C	FIN	12	7C	ISZ 12	BC	XCH 12	FC	KBP
3D	JIN	12	7D	ISZ 13	BD	XCH 13	FD	DCL
3E	FIN	14	7E	ISZ 14	BE	XCH 14	FE	-
3F	JIN	14	7F	ISZ 15	BF	XCH 15	FF	-

MOSAIC

Absolute Maximum Ratings*

Ambient Temperature Under Bias	0°C to 70°C
Storage Temperature	-55°C to + 125°C
Input Voltages and Supply Voltage with respect to V _{SS}	+0.5V to -20V
Power Dissipation	1.0 Watt

*COMMENT:
Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

D.C. and Operating Characteristics

T_A = 0°C to 70°C; V_{SS} - V_{DD} = 15V ± 5%; t_{φPW} = t_{φD1} = 400 nsec; logic "0" is defined as the more positive voltage (V_{IH}, V_{OH}); logic "1" is defined as the more negative voltage (V_{IL}, V_{OL}); Unless Otherwise Specified.

SUPPLY CURRENT

Symbol	Parameter	Min.	Limit Typ.	Max.	Unit	Test Conditions
I _{DD}	Average Supply Current		30	40	mA	T _A =25°C

INPUT CHARACTERISTICS

I _{LI}	Input Leakage Current		10	μA	V _{IL} =V _{DD}
V _{IH}	Input High Voltage (Except Clocks)	V _{SS} -1.5	V _{SS} +.3	V	
V _{IL}	Input Low Voltage (Except Clocks)	V _{DD}	V _{SS} -5.5	V	
V _{IL0}	Input Low Voltage	V _{DD}	V _{SS} -4.2	V	4004 TEST Input
V _{IHC}	Input High Voltage Clocks	V _{SS} -1.5	V _{SS} +.3	V	
V _{ILC}	Input Low Voltage Clocks	V _{DD}	V _{SS} -13.4	V	

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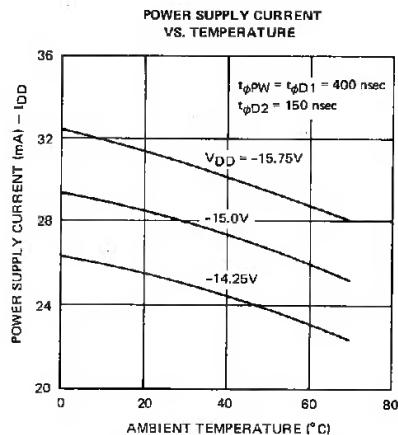
OUTPUT CHARACTERISTICS

I _{LO}	Data Bus Output Leakage Current		10	μA	V _{OUT} =-12V
V _{OH}	Output High Voltage	V _{SS} -.5V	V _{SS}	V	Capacitance Load
I _{OL}	Data Lines Sinking Current	8	15	mA	V _{OUT} =V _{SS}
I _{OL}	CM-ROM Sinking Current	6.5	12	mA	V _{OUT} =V _{SS}
I _{OL}	CM-RAM Sinking Current	2.5	6	mA	V _{OUT} =V _{SS}
V _{OL}	Output Low Voltage, Data Bus, CM, SYNC	V _{SS} -12	V _{SS} -6.5	V	I _{OL} =0.5mA
R _{OH}	Output Resistance, Data Line "0" Level	150	250	Ω	V _{OUT} =V _{SS} -.5V
R _{OH}	CM-ROM Output Resistance, Data Line "0" Level	320	600	Ω	V _{OUT} =V _{SS} -.5V
R _{OH}	CM-RAM Output Resistance, Data Line "0" Level	1.1	1.8	kΩ	V _{OUT} =V _{SS} -.5V

CAPACITANCE

C _φ	Clock Capacitance	14	20	pF	V _{IN} =V _{SS}
C _{DB}	Data Bus Capacitance	7	10	pF	V _{IN} =V _{SS}
C _{IN}	Input Capacitance		10	pF	V _{IN} =V _{SS}
C _{OUT}	Output Capacitance		10	pF	V _{IN} =V _{SS}

Typical D.C. Characteristics



A.C. Characteristics

$T_A = 0^\circ\text{C}$ to 70°C , $V_{SS} - V_{DD} = 15\text{V} \pm 5\%$



Symbol	Parameter	Min.	Limit Typ.	Max.	Unit	Test Conditions
t_{CY}	Clock Period		1.35	2.0	μsec	
$t_{\phi R}$	Clock Rise Time			50	ns	
$t_{\phi F}$	Clock Fall Times			50	ns	
$t_{\phi PW}$	Clock Width	380		480	ns	
$t_{\phi D1}$	Clock Delay ϕ_1 to ϕ_2	400		550	ns	
$t_{\phi D2}$	Clock Delay ϕ_2 to ϕ_1	150			ns	
t_W	Data-In, CM, SYNC Write Time	350		100	ns	
$t_H^{[1,3]}$	Data-In, CM, SYNC Hold Time	40		20	ns	
$t_H^{[3]}$	Data Bus Hold Time During M_2-X_1 and X_2-X_3 Transition.	150			ns	
$t_{OS}^{[2]}$	Set Time (Reference)	0			ns	
t_{ACC}	Data-Out Access Time Data Lines Data Lines SYNC CM-ROM CM-RAM			930 700 930 930 930	ns ns ns ns ns	$C_{OUT} = 500\text{pF}$ Data Lines 200pF Data Lines ^[4] 500pF SYNC 160pF CM-ROM 50pF CM-RAM
t_{OH}	Data-Out Hold Time	50		150	ns	$C_{OUT} = 20\text{pF}$

Notes: 1. t_H measured with $t_{\phi R} = 10\text{nsec}$.

2. t_{ACC} is Data Bus, SYNC and CM-line output access time referred to the ϕ_2 trailing edge which clocks these lines out. t_{OS} is the same output access time referred to the leading edge of the next ϕ_2 clock pulse.

3. All MCS-40 components which may transmit instruction or data to the 4004 at M_2 and X_2 always enter a float state until the 4004 takes over the data bus at X_1 and X_3 time. Therefore the t_H requirement is always insured since each component contributes $10\mu\text{A}$ of leakage current and 10pF of capacitance which guarantees that the data bus cannot change faster than $1\text{V}/\mu\text{s}$.

4. $C_{DATA BUS} = 200\text{pF}$ if 4008 and 4009 or 4289 is used.

4004

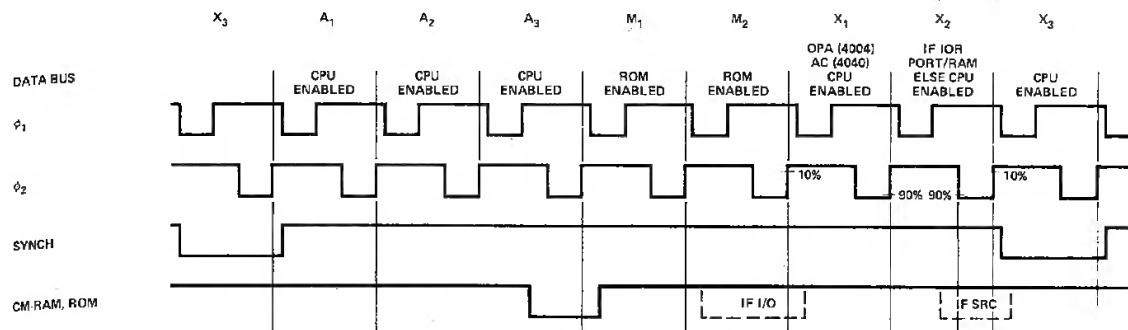


Figure 1. Timing Diagram.

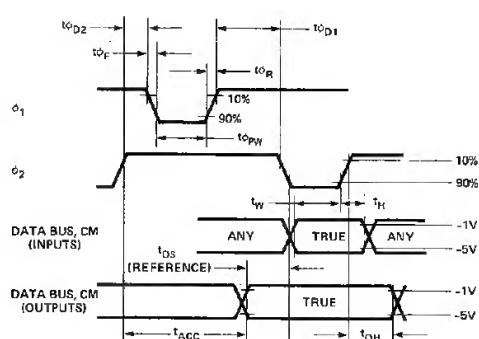


Figure 2. Timing Detail.